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EFFICIENT SPATIAL PLACEMENT OF FUELS TREATMENTS

Final Report

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Challenge Cost-Share Study
Between
University Of Montana, School of Forestry
And
United States Department of Agriculture
Forest Service
Rocky Mountain Research Station
Research Work Unit Number 4802

By

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This report consists of two parts. An existing report (part A) was filed for the benefit of the Pike, San Isabel National Forest (PSI NF) and others in order to inform and to solicit assistance in work yet to be done. Part A of this report was presented by Edward Butler in February of 2005 and includes the work of all three modeling teams. Part B is an update of study progress, which details accomplishments from February to May of 2005. Although funding for this study ended on May 31, 2005 the work continues under alternative funding from the study titled "Optimizing landscape treatments for reducing wildfire risk and improving ecological sustainability of ponderosa pine forests with mixed severity fire regimes," which will be exhausted by the end of federal fiscal year 2005.

From the outset, it was believed that this study could be joined with similar studies, each interested in slightly different aspects of ecology, but with the common benefit of hazardous fuels mitigation on the Colorado Front Range. These cohort studies did mutually benefit from the cooperative effort both in knowledge gleaned and work expended. This study has had numerous, unforeseen difficulties that have slowed its progress. Much of the delay has been suffered by the MAGIS team because of our difficult position in the development of this study. Both the SIMPLLLE and Fire Behavior models are able to function independently of MAGIS, but our study design calls for MAGIS to incorporate the outputs of those models. The MAGIS team has therefore, latently suffered all delays experienced by the companion modeling teams. Other obstacles have been unforeseen difficulties in incorporating new considerations into MAGIS planning solutions. With the completion of this study the research & development team will have enhanced the functionality of MAGIS through the integration of: WEPP erosion modeling; Fire behavior outputs; Fire Regime Condition Class modeling; in-house SIMPPLLE modeling and other auxiliary modeling to address specific client considerations.

STUDY:

Developing an effective spatial fuel treatment strategy to reduce wildfire spread and intensity levels on the Colorado Front Range.

Problem and Objectives

Large fires under extreme weather conditions in 2002, like the Hayman fire in Colorado and the Rodeo-Chediski fires in Arizona are the most damaging to forest resources (watersheds, forest ecosystems, wildlife habitat) and developed communities, and therefore must be the target of fuel treatments. However, many factors limit the number of acres of fuel treatments that can be accomplished, for example, budgets, prescribed burning windows, and smoke production. It is therefore important to develop strategies that effectively address fuel treatment objectives with the limited number of acres than can be treated. The position and spatial arrangement of fuel treatments on a landscape determine their ability to disrupt the growth of large fires. This study will apply a suite of models that range in scale from individual plant communities to entire landscapes to develop and evaluate alternative spatial strategies for treating fuels within the limiting factors identified by land managers. The study will be conducted on a 100,000+ acre area within the Colorado Front Range. Modeling analysis will cover up to five decades to evaluate both short- and long-term cumulative effects of fuel treatments. The unique contribution of each type of model will be documented.

Overview of Models Involved in the Study

Fire behavior modeling

The FARSITE Fire Area Simulator (Finney 1998) is the state-of-the-art model for predicting the spread and intensity of fires across a landscape. It is designed to model continuous fire behavior over multiple burning periods at a 30-meter resolution in the raster map environment. It requires spatial data for elevation, slope, aspect, surface fuel model, canopy cover, crown base height, crown bulk density, and stand height. FARSITE is able to compare effectiveness of different suppression strategies and treatments for containing fire under varying weather conditions. FARSITE output layers include fire perimeters over a given period of time, rate of spread, fireline intensity, flame length, and heat per unit area, as well as indicators of severe fire behavior, including torching, spotting, and crowning. FARSITE evaluations are based on simulating fires starting at various locations and spreading under varying fuel and weather conditions. There is, however, no extended temporal component to these analyses; fire behavior is dependent only on a current snapshot of the underlying vegetation. Therefore, there is no indication of the long-term effectiveness of a spatially explicit schedule of vegetation treatments.

Finney (2002a) developed a fire growth simulator that uses minimum travel time methods to simulate how fast one fire or a band of multiple fires are expected to move across a landscape. It is used to identify the routes where fire is expected to travel most quickly. As with FARSITE,

these simulations are based on the current fuels, specific locations for fire starts, and weather conditions. If one accepts that fuel treatments should be prioritized on the basis of juxtaposition of high values to hazardous fuels, this program begins to give us the ability to develop a biophysical definition of wildland-urban interface based on the distance fire can travel under specified conditions.

The Treatment Optimization Model (TOM) uses minimum travel time logic to determine effective locations for fuel treatments on a landscape (Finney 2002b). The treatment locations are based on the fire behavior expected from the current fuels present on the landscape, specific locations for fire starts, and weather conditions. The solutions suggest location, sizes, and orientations of fuel treatments that are efficient and effective at changing large fire growth by reducing the fire spread rate. The treatment locations are selected to reduce the rates of fire spread across the landscape, and are not designed to protect specific locations on a landscape, such as designated wildland-urban interface. Also, the placement of treatments does not consider feasibility factors associated with location (such as roads) or shape, nor do they address resource effects, or management limitations such as budget.

Landscape simulation modeling

SIMPPLLE is a stochastic simulation model for projecting the temporal changes in the spatial distribution of vegetation in the presence and interaction of insects, disease, and wildland fire (Chew 1997, Chew and others 2004). Simulations can be made with or without fire suppression, with or without fuel treatments, and under average or extreme fire conditions. Spread logic is included for wildland fire and other disturbance processes. The location and frequencies of disturbance processes quantified from multiple stochastic simulations provide estimates of the location and probabilities of future disturbance processes. These provide a basis for identifying "problem areas," as well as estimating costs and effects associated with disturbance processes.

Treatment scheduling modeling

MAGIS is an optimization model for spatially and temporally scheduling treatments that effectively meet resource and management objectives while satisfying user-imposed resource and operational constraints (Zuuring and others 1995, Jones and Chew 1999) MAGIS accommodates a wide variety of types of land management treatments, and associated costs, revenues, and effects. MAGIS also contains a road-network component for analyzing road construction, re-construction, and closure. The combination of the land management and road-network components provide the capability to include the limitations and costs associated with access in spatially analyzing fuel treatments.

Comparing the types of models

These models vary in the aspect of the fuel treatment planning problem they address, and differ in terms of data requirements, timeframes they analyze, and what is included in the analysis. These differences suggest roles or niches for these types of models. The fire behavior-based models provide state-of-art analysis of fire spread across a landscape with specific weather conditions. They are used to identify locations most likely to have high rates of fire spread and severe fire. This is valuable information, but it stops short of integrating other resource issues

and management limits into a spatial treatment pattern. MAGIS develops spatial treatment schedules that can incorporate treatment costs and revenues, budget and manpower limitations, environmental limitations on air quality and hydrologic thresholds by drainage. The analysis conducted by fire behavior models is based only on the current fuels present on a landscape. There is no capability to incorporate the change over time needed to analyze both spatial and temporal treatment patterns, as is done in both MAGIS and SIMPPLLE. The fire behavior models provide detailed modeling of fire spread using a physical fire behavior approach. They, however, do not model fire in a spatial, temporal ecological context, as is done with SIMPPLLE. This spatial, temporal, and ecological context provides a valuable framework for analyzing likely outcomes of spatial treatment strategies over time – are desired future conditions (including fuel conditions) achieved by the treatment strategy? These capabilities in the hands of managers provide powerful tools for developing treatment strategies and presenting the ecological, economic, and fire/fuels logic for those strategies to the public. Furthermore, these tools can be used effectively across jurisdiction boundaries, by incorporating economic and resource issues unique to each jurisdiction.

Modeling Framework

Comprehensive Optimized Project Planning for Ecosystem Restoration (COPPER) is the name given to this joint modeling system. This Forest Service concept of collective modeling has been structured so that it exists as a flexible mix of modeling tools that can be customized for this or future projects. It is designed so that the mix of these modeling tools will permit unique and complementary analyses to address the multi-faceted and complex job of forest planning. This is the first time these modeling tools have been used cooperatively by the Forest Service to this extent and there are working relationships and procedures to refine among models and modeling teams. Figure 1 presents a flowchart of model interactions.

Logistical Flowchart COPPER:

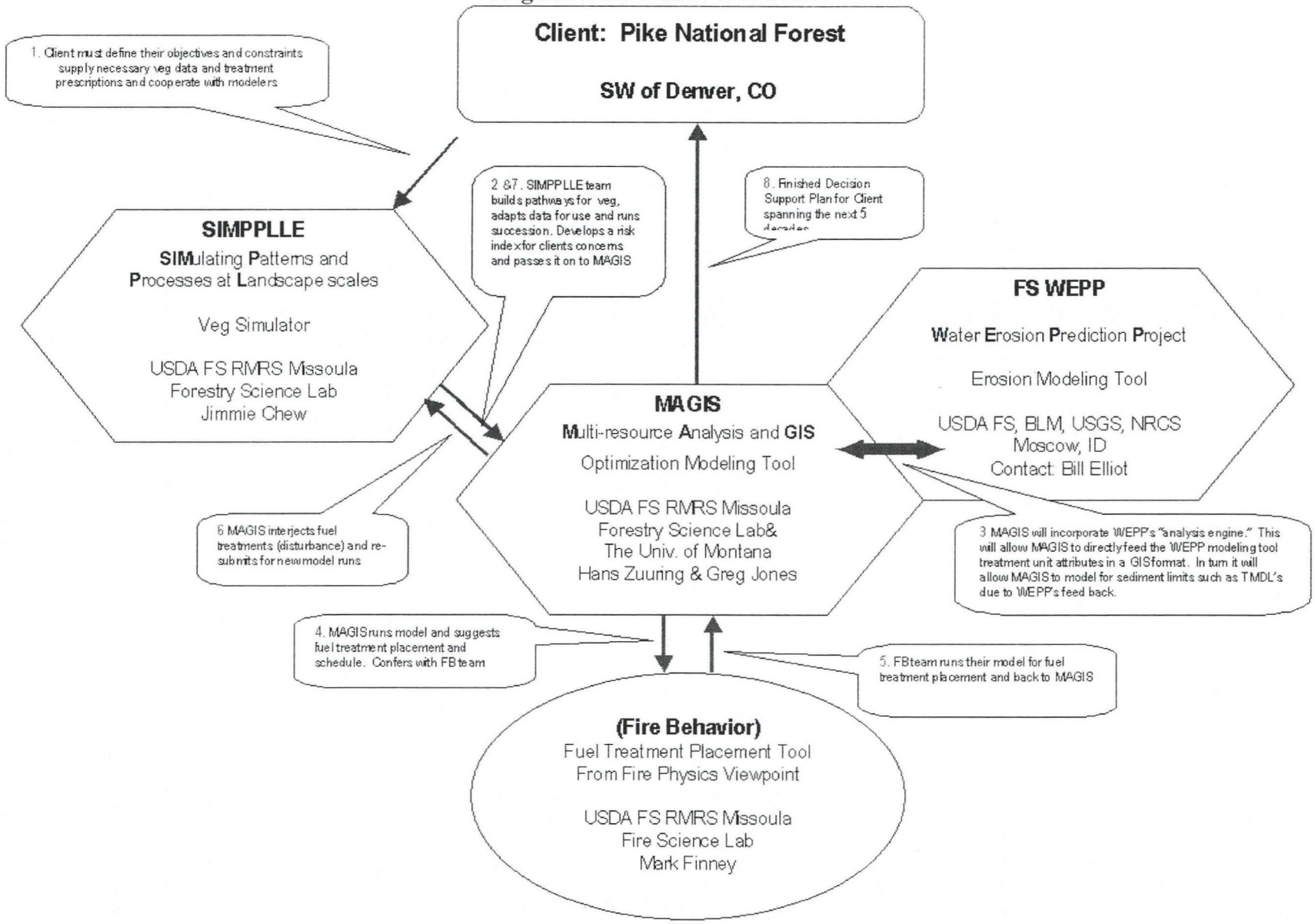
Client: Pike National Forest
SW of Denver, CO
1. Client must define their objectives and constraints supply necessary veg data and treatment prescriptions and cooperate with modelers
2 &7. SIMPPLLE team builds pathways for veg, adapts data for use and runs succession. Develops a risk index for clients concerns and passes it on to MAGIS
8. Finished Decision Support Plan for Client spanning the next 5 decades
SIMPPLLE
SIMulating Patterns and Processes at Landscape scales
Veg Simulator
USDA FS RMRS Missoula
Forestry Science Lab
Jimmie Chew
FS WEPP
Water Erosion Prediction Project
Erosion Modeling Tool
USDA FS, BLM, USGS, NRCS
Moscow, ID
Contact: Bill Elliot
MAGIS
Multi-resource Analysis and GIS
Optimization Modeling Tool
USDA FS RMRS Missoula
Forestry Science Lab&
The Univ. of Montana
Hans Zuuring & Greg Jones
6 MAGIS interjects fuel treatments (disturbance) and re-submits for new model runs
3 MAGIS will incorporate WEPP's "analysis engine." This will allow MAGIS to directly feed the WEPP modeling tool treatment unit attributes in a GIS format. In turn it will allow MAGIS to model for sediment limits such as TMDL's due to WEPP's feed back.
4. MAGIS runs model and suggests fuel treatment placement and schedule. Confers with FB team
5. FB team runs their model for fuel treatment placement and back to MAGIS
(Fire Behavior)
Fuel Treatment Placement Tool
From Fire Physics Viewpoint
USDA FS RMRS Missoula
Fire Science Lab
Mark Finney

Figure 1

Study Progress Part A

Data

The study plan specified the use of remotely sensed hyperspectral imagery to delineate current fuels and vegetation on the landscapes to be modeled. In May of 2004, the COPPER teams were briefed by CSU's Ingrid Burke, that AVIRIS remotely sensed imagery would be supplied for our data needs. Attribute requirements for the models were discussed with Prof. Burke and personnel from the RMRS Ft. Collins office.

The AVIRIS project was hoped to supply a higher quality of data resolution and attributes than had previously been available from LANDSAT 7 ETM. It was expected that the finer spectral resolution of 224 spectral bands rather than 7 and that the higher spatial resolution of $20m^2$ as opposed to $30m^2$, would yield not only better identification of vegetation species, but also serve as a stronger basis for crown and structure synthesis. It was hoped by all participants that through interpretation techniques, the required attributes could be synthesized. The data were received at the end of September 2004, and were found to be lacking key attributes for modeling use.

For SIMPPLLE's purposes, the data lacked stand structure and habitat type. Habitat type could have possibly been completed with surrogate data, but stand structure could not. Further, only two species of vegetation, ponderosa pine and Douglas fir, were supplied in the data with the remaining land cover left as "no-data." This would limit SIMPPLLE's ability to model for the full range of succession, disturbance and process spread or "contagion."

MAGIS requires components of stand structure such as density class and size class of tree species involved. MAGIS runs would be very limited due to the absence of tree species from the data.

The SIMPPLLE and MAGIS teams proceeded to work with the preliminary study areas of Trout Creek, Wet Mountains, and Harris Park to prepare and calibrate their models in the hope that subsequent AVIRIS interpretation would yield the required attributes. With the exception of the Wet Mountains area chosen as one of SIMPPLLE team's sites, all preliminary datasets are subsets of the AVIRIS coverage. Building the framework of the model is a significant portion of the work involved and adapting additional data or sites can be easily done; working with alternate datasets allowed progress to continue. We are now at the culmination of our preparation and must proceed with the best available data, which is apparently not the AVIRIS set.

Regarding the needs of the fire behavior team, data required are: surface fuel model, canopy cover, crown base height, crown bulk density, and stand height. The fire behavior team also finds the AVIRIS data insufficient. They have expressed continued hope that data improvements from CSU and Ingrid Burke's AVIRIS team will allow this, but will soon be forced to use other data should it not materialize.

For a final update on data, the third AVIRIS data submission has just been forwarded to us. There is no difference in the suitability of this version for SIMPPLLE and MAGIS over previous versions. None of the missing attributes have been provided.

Although further refinement of the AVIRIS dataset has occurred, no change in suitability of the data has occurred. However, the data will be used by the fire behavior team in their modeling work.

Steps SIMPPLLE team accomplished to build this model

Step 1 Build Vegetation Successional Pathways and Disturbance Processes for Colorado

Pathways
The SIMPPLLE team conducted an extensive study into vegetation species, habitat types, size classes of species, densities, and the successional characteristics that are indigenous to Colorado. This information forms the classification system into which any submitted "current vegetation" dataset might fit. Both pathways and disturbance processes (below) were researched by cooperator Thad Jones over a period of one year. These were based on an extensive literature review as part of a master's thesis, under the supervision of University of Montana professor Don Bedunah, Ph.D., who completed his MS from Colorado State University in 1977. Dr. Bedunah has had previous experience developing vegetative pathways in Colorado for other vegetation simulation modeling tools. 195 vegetation species, 6 habitat types, 20 size classes and four density classes were defined.

Disturbance Processes
Disturbance processes modify natural succession in SIMPPLLE and force a change to an alternate pathway. Disturbance processes were part of the above study, but deserve separate consideration. There were 19 defined for this study. Examples would be: two severity classes of mountain pine beetle, three classes of fire severity, windthrow, and root disease. This work too was also done by cooperator Thad Jones. The classification of pathways and disturbance processes and other classifications are documented in the attached spreadsheet *Appendix - CFR-Legals90104.xls.*

Step 2 Import Current Vegetation Data Layer for Colorado Front Range Study

SIMPPLLE must have properly attributed data of current vegetation types. Required attributes for SIMPPLLE are dominant species, size class, density, and habitat type. The SIMPPLLE team and other teams were unable to use the insufficiently attributed AVIRIS data. The SIMPPLLE team possessed other properly attributed, but less current datasets from the general area of interest on the Colorado Front Range.

Other Work by SIMPPLLE related to this Study

SIMPPLLE is also using this information to facilitate a Colorado study on the Mesa Verde National Park in cooperation with the USGS.

Work Remaining to be done by SIMPPLLE

The SIMPPLLE model is ready to be run to simulate the no action alternative (stage two in Figure 1), once the landscape data issue discussed earlier is settled. SIMPPLLE will be run again later in the process (step seven in the flowchart to simulate fire and other disturbances given the treatment alternatives.

SIMPPLLE's development team has followed through with the initial "no action" simulation modeling for five periods and provided a risk index map for fire hazards and although not requested, pine beetle infestation. It is planned that the fire hazard risk index will be used in MAGIS' optimization modeling. The SIMPPLLE team also has provided the MAGIS team with advice on pathway logic.

Steps MAGIS team accomplished to build this model

The MAGIS team's emphasis in COPPER is focused on management activities and consequently requires in-depth development of relationships with personnel of the forest and region. Also inherent in every discussion is what information and cooperation we need back from them; cooperation once attained, is ongoing. Our contacts and discussions include:

Ted Moore	Fuels and Fire Manger for the Pike	Many discussions early on. Truly the heart of our work has been discussed with Ted. Nearly every aspect of his daily work corresponds with our concerns.
Elise Bowne	GIS modeler for Region	Extensive discussions and correspondence with Elise. Supplied important supplemental data for our work and was a strong source for information and other contacts. A very helpful and enthusiastic employee.
Ed Biery	GIS modeler on special projects	Discussions with Ed involved his extensive knowledge of the CVU project (R2 VEG), which later became our best available vegetation data.
Carl Owens	GIS librarian and modeler for the Pike	Carl supplied several data layers integral to our work
Brian Banks	GIS modeler for the Cheeseman Restoration	Discussion with Brian always yielded beneficial information, and on two occasions helpful data layers.
Melinda McGann	Remote Sensing Specialist for Region	Discussion yielded no beneficial data, but contributed to an overall understanding of who holds data.
Deb Entwistle	Hydrologist across several forests	Early on and often we discussed hydrology issues. Deb, requested FS WEPP be a part of COPPER
Dana Butler	Hydrologist on the Pike	Contacted, but most communication and information came from Deb Entwistle who had previously held this position.
Lee	Prof. of	Corresponded information on the study. Point was to introduce

McDonald	Hydrology CSU	our work and get info on other projects in the area.
Floyd Freeman	Silviculturalist on the Pike	Entered discussions with Floyd only a month ago, now that we are defining prescriptions. Floyd will be key to our work and I hope our work key to his.
Fred Patten	Analyst for the Pike	Team member Kevin Hyde had detailed discussion with Fred, who is familiar with our type of work via his experience with a seminal type (non-spatial) of our model – IRPM. It is our hope that Fred can share his understanding of modeling with interested parties in the study area.
Mark Jacobson	Director Info. Manage. and GIS - USFWS	Provided Mexican spotted owl information and GIS layers
Terri Thorn	Wildlife Biologist - USFWS	Provided GIS layers for Preble's meadow jumping mouse critical habitat.

Other progress for the MAGIS team:

- Collected extensive spatial data layers and created a GIS of the study area. MAGIS team Coordinated with GIS modelers on the Pike.
- The MAGIS team, before receiving the datasets from SIMPPLLE, used the time for literature review and model refinement.
- The MAGIS team performed a detailed study on biomass utilization. *See Biomass section for further detail.*
- For the study's focus on fuel treatments and prescribed burns, the study's two implementation team members studied the topic by completing a graduate course in landscape fire ecology.
- MAGIS team members researched hydrology issues relevant to the study area and conferred with hydrologists in the CFR about special concerns.
- Implementation team members and developers for MAGIS conferred and planned for the FS WEPP integration for erosion modeling.
- MAGIS team researched threatened and endangered species on the study area. Mexican spotted owl, Pawnee montane skipper butterfly, and Preble's meadow jumping mouse were identified as threatened and endangered species to include as special management zones. GIS data sets were obtained from wildlife biologists.
- Researched and conferred with the Elise Bowne on a multi-forest fire-hazard study of values at risk, coordinated by Elise in 2002. Incorporated values at risk/weighted average study from Region 2 into the MAGIS model. This prioritized a combination of erosion risk, housing density, and threatened and endangered wildlife habitat.
- Performed a detailed search for GIS data to augment values at risk/weighted average study's housing density layer. Performed registration adjustments and determined that it did not significantly improve on the prior work
- Relationships among the models were discussed with interested parties, planned and put in the form of a flowchart. (See Figure 1)

- MAGIS received SIMPPLLE's datasets and performed necessary quality checks, adaptations and further customized MAGIS for the study.
- A MAGIS model is built for a watershed within the study area known as Trout Creek.
- Three presentations have been made to the College of Forestry, University of Montana based on the PowerPoint™ "Primer on Modeling and Introduction to COPPER."-- study was well received. This PowerPoint™ was re-written presentation to a general-interest audience and is provided along with this documentation for further reference.
- Team members Robin Silverstein and Edward Butler presented a poster entitled Colorado Front Range Fuel Treatment Optimization Modeling at the Association for Fire Ecology's Mixed Severity Fire Regimes: Ecology and Management Conference, held in Spokane, WA, November 17-19, 2004. Interest in the poster from the attendees was strong.

Part B (Progress, March and April 2005)

Part A of this report was delivered to the PSI NF, and others at a Front Range Fuel Treatment Project FRFTP meeting in Denver, February 15th. Edward Butler and Greg Jones represented the MAGIS, COPPER CFR study for all three teams. The meeting was instrumental in the interchange of ideas with the Forest and other stakeholders. From this meeting a final 92,000-acre study site comprised of several 6th code hydrologic units (Buffalo Creek, Pine-Rowland, Lowermost North Fork of the South Platte, and Waterton-Deckers) was confirmed. This long awaited decision released the MAGIS modelers to proceed with work on several topics.

- Treatment methods were designed with the aid of Merrill Kaufmann of the PSI NF.
- Economic aspects of the site and methods were developed and detailed with the help of Kaufmann, Fred Patten, Chuck Dennis and others.
- Determinations about merchantable outputs such as timber harvest and biomass utilization were made.
- Discussions with the WEPP modeling group began in earnest to incorporate WEPP's erosion prediction functions into MAGIS via look up tables and batch processing.
- Discussions with the Regional Hydrologist for the PSI, Deb Entwistle began in earnest to build consensus regarding WEPP function via MAGIS modeling.
- I cooperated with Dan Loeffler of RMRS-Missoula on a cooperative biomass utilization study. This study also benefits **"Developing an effective spatial fuel treatment strategy to reduce wildfire spread and intensity levels on the Colorado Front Range"** by providing yield and economic information prioritization.
- With many decisions made regarding the treatments and scheduling how to prioritize the work on the study site, attribution of the data was developed. All pertinent variables expressed to be controlling factors in our optimization work must be attributed up in the data. This attribution may take the form of qualitative or quantitative information broken up into geographical zones. Also input at this step are any attributes necessary to set up relationships between (adjacency) treatment

units. There is a great deal of manipulation work involved in the attribution step. For detail:

- Though the current vegetation data was provided in a format used by MAGIS, a number of nomenclature conversions and crosswalk actions were required and performed.
- The data were delivered as spatial data and delineated by stand. Some very sinuous polygons were identified which will cause difficulties in modeling if not corrected. These polygons were broken into smaller entities having a more uniform size of 3-50 acres.
- Quality checking of the data was performed.
- The data were attributed with elevation, slope and aspect.
- These attributes were manipulated into significant classifications.
- The data were attributed with zones for inclusion/exclusion regarding treatment consideration or other zonal functions regarding what type of treatments are allowed on a given stand.
- I performed a detailed climate study of the site and determined there was little variation between nearby sites. A single climate will be used for erosion modeling.
- I worked out a nagging registration issue between the AVIRIS dataset (used by the fire behavior team) and our CVU data. The AVIRIS had been incorrectly documented with a datum of NAD83–it should have been NAD27.
- I performed a study in soil science and to the study site's soil types to support WEPP integration.
- I worked with Ken Kanaan, soil scientist to the Region and PSI NF, to develop soil attribution for the vegetation stand data.
- Buffered streams, roads and developed zones for prioritization of treatments that will be linked with WEPP erosion prediction.
- Buffered structures on the study site. Researched wildfire and urban interface issues precedents and methods. With help from others in the Research unit, a plan was developed to combine a structures protection layer with a housing density layer for treatment prioritization in the WUI.
- I worked with Kevin Hyde and Janet Sullivan to develop logic and necessary attribution for production and delivery zones for WEPP modeling needs.

- I am documenting this work in a thesis format and have completed the introduction; it is now in the second draft with little further revision anticipated.

This report is filed at what is the end of the model building process and starts the scenario building stage.

Work completion imminent, but pending

- Erosion modeling via the FS WEPP program is in its final stage of incorporation into MAGIS. This will not be a new process since we have incorporated functionality of other models in previous projects. We did, however, have several challenges in determining WEPP's sensitivity to several variables. Incorporation into our model is coming to completion in the hands of MAGIS's developers now.

- The MAGIS team has developed detailed plans for incorporating the Fire behavior modeling outputs in our work. A meeting is scheduled with the Fire behavior team to work out the final details on June 17th.

Work remaining for the MAGIS team

- Biomass-yield estimation logic will have to be incorporated into MAGIS. I am told this has been developed by Dan Loeffler of our research unit and is ready for completion, but waiting for other issues to be resolved.
- Robin Silverstein and I plan to learn to run SIMPPLLE by ourselves because we need to model our processes iteratively in decadal time-spans so as not to detrimentally affect the accuracy of our modeling. Further we anticipate that the time spent learning and making the various SIMPPLLE runs is worthwhile since that ability will permit immediate answers to be generated from in-house SIMPPLLE simulations. This is a preferred alternative rather than losing time waiting for and relying on, other parties to perform the necessary iterative model simulations between the SIMPPLLE and MAGIS.
- Documentation must be completed. The methods section is in process and developing as does the modeling work.

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